DESIGN AN INTEGRATED SYSTEM BETWEEN FINITE ELEMENT ANALYSIS AND LIFECYCLE QUALITY MANAGEMENT TO OPTIMIZE TYPICAL DESIGN OF ONE INDUSTRIAL PARTS

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Abstract: *This paper discusses the concept of Quality Lifecycle Management and the benefits of creating an integrated system between it and finite element analysis to improve the design of the products. The steps in gathering data from both FEA and QLM processes are presenting. As a model for a case study, we present a design for the turbine-blade model.*

Keywords: *Finite Element Analysis, Digital Manufacturing, Life-cycle Quality, Management*

1. Introduction

Quality assurance and efficient management are basic titles for any successful industry in our days, furthermore using computer simulation and Numerical analysis should the keys to obtaining these goals in the global market. Designers and managers can get benefits from science and technology to achieve the best possible product in the lowest possible cost.

The new approach in Quality management can be seen now by using simulation to improve life-cycle quality for any type of products, which leads us more and more toward hybrid industry and automation design [Quiz et al., 2012].

2. Quality Lifecycle Management (QLM)

2.1 QLM definition

Quality lifecycle management is a multidimensional process which provides solutions to manage all aspects in product quality and reliability; however, this process has to start early in product development and design and continuously be applied in following levels like products, validation, quality assurance, etc. In creating products the numerical model of product uses CAD tool. When the final product is designed the variability management in product life cycle become an important issue in the product-process design [Nguyen, 2014].

Quality lifecycle management (QLM) promotes information about the quality process and assures product's reliability using methods that are fully integrated into the product development lifecycle and highly visible to all personnel with a stake in product quality [Fang et al., 2016]. Quality management must connect all activities related to quality in one procedure, easy to follow and control, from the design level to cost planning and risk estimation. Figure 1 shows the QLM continues cycle which works to improve activity in the production line [PTC, 2011].

As we see in Figure 1 QLM will accompany the designer and the manager in each step during the production, so the lifecycle of the product will be controlled step by step to minimize the errors and assure that we will have production driven by quality. Indeed, we need criteria for every step, for example designers will have criteria to which part needs more support and improvement, test engineers have criteria to define which character must be tested, manufacturers have to know which aspect will be controlled in the production line, and service section will have a clear plan to do maintenance and repairing respecting to product performance and properties [PTC, 2011].

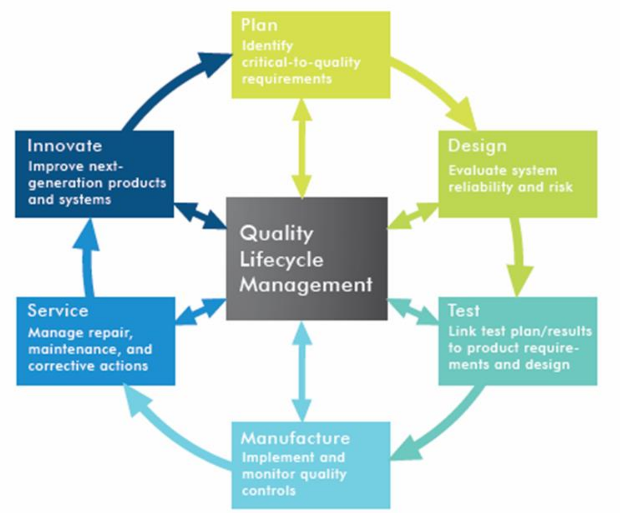

Figure 1: *QLM process [PTC, 2011]*

2.2 QLM Challenges

Achieving quality in the production process will meet many challenges because there is no ideal environment or system for quality management; however, QLM is designed to overcome these challenges during the lifecycle of the product if it applied in the right way. Basic challenges in the production process are as following:

1 - Quality of each specific product must be defined by the producer because every product has a special purpose with the quality concept, conditions, and criteria.

2 - The need for gathering, organizing, documenting and promoting quality information for all the production levels and providing the ability to access this information for all responsible staff.

3 - Enroll quality rules in the management system and production process to have an integrated procedure of quality [Romero and Vieira, 2014].

The design of products needs to develop a risk identification process. This process must take into account all the risk during the life cycle of the product. Risk identification should be made in a rigors' manner for all the steps of QLM. Ideally, a list with the inputs of each fazes of life cycle should associate the risks that can occur. The management of the risk is important because identified and evaluation of the risk can prevent the failure due to major risk that can be identified and measured before the risks are manifesting and produce. For each risk that is identified, from the first steps of the life cycle, must establish a measure to decrease its effect in the subsequent steps.

3. An Overview of Numerical Analysis

Numerical Analysis is the method to use numerical approximation for equations in mathematical analysis. Numerical calculation creates a great chance to use simulation engineering for all kinds of engineering projects using the high power of computers in our days. This analysis concentrates on obtaining approximate solutions for our problem with an acceptable margin of errors [Haidar, 2017].

The main idea of numerical analysis is to study the physical model of our problem and obtain a suitable mathematical model that describes the problem and can control the variables and push forward for a solution. The mathematical model means use approximate functions to change differential equations to integral algebraic ones, so we can use the power of computers to solve the new matrix of equations.

Based on computational discretization methods to divide geometry and enter boundary conditions we can discuss three basic methods for numerical analysis:

1- 1- Finite Element Method (FEM);

2- 2- Finite Volume Method (FVM);

3- 3- Finite Difference Method (FDM).

3.1 FEM

FEM is a computational method to divide the geometry (CAD model) into small finite-sized elements in the simplest possible shape, the name of this network of elements is Mesh, and we call the contacts points between elements Nodes. In this method, dependent values are stored at the elements and nodes.

3.2 FEM basics

This method is the most difficult to apply however it has the best accuracy especially in complex CAD models, because of that we will concentrate on this method and its basics and applications.

For applying FEM for engineering model we need first to specify the physical governing equations which control the model, then to obtain mathematical model we need to change PDE to integral equations using approximate functions (linear, nonlinear, quadratic polynomial, etc.) [Fang et al., 2016].

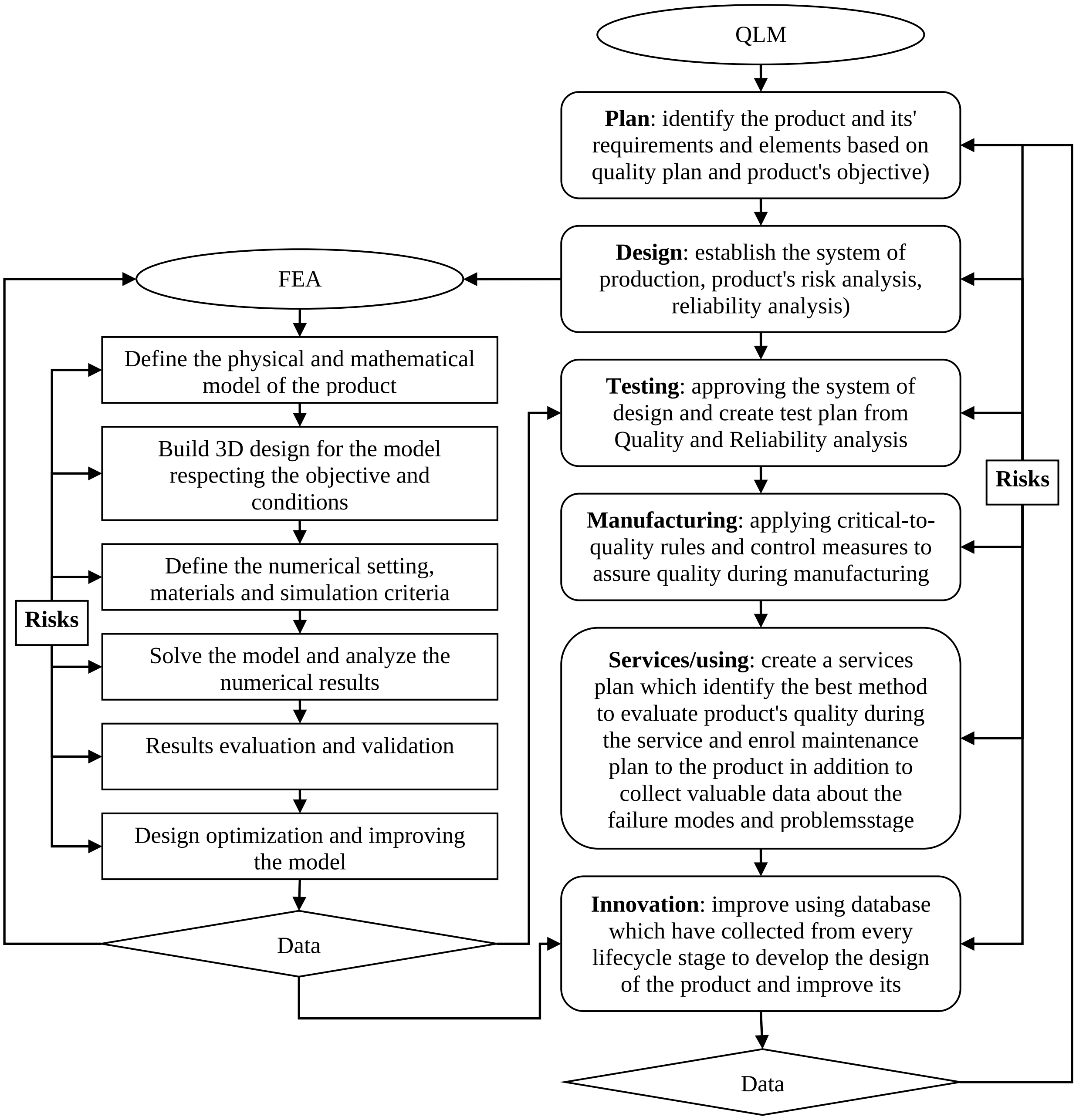

Figure 2: *FEA-QLM integrated flow chart*

Using this functions and creating the Mesh which contains elements and nodes with a specific number of Degree of Freedom (DOF) lead us to end up with a large sparse matrix equations system that can be solved by power calculation of computers [Haidar, 2017].

3.3 FEA Industrial Applications

Nowadays engineers can use FEA to simulate almost all engineering problems and analysis (structural analysis, heat transfer, flux and fluid dynamics, electromagnetic, etc). In machine manufacturing field we can mainly distinguish three basics applications:

1 - Design optimization

2 - Test quality and reliability for mechanical parts.

3 - Improve manufacturing Process for mechanical assembly [Haidar, 2017; Allison and Herbert, 2014].

4. Integrated FEA and QLM system

4.1 FEA-QLM Flowchart

A new efficient system designed to integrate FEA process in QL Management and got benefits from both to improve the quality is presented.

The basic step in any quality procedure is to collect data and analyze them in the best possible way, so this system relays on gathering data from both FEA and QLM processes and create an effective database which will help the designers and managers to push over the product's quality and reliability forward in lower cost and time. Figure 2 illustrates the flow chart of new integrated system between FEA process and QLM flowchart [Haidar, 2017; Chryssolouris et al., 2009].

4.2 FEA-QLM cycle

FEA provides a very good source of data to the designer about the product's behaviour under many scenarios of loading and working, furthermore helps them to analyze data and evaluate the results.

In engineering projects testing the prototype models for any products needs a big budget and time, while by using numerical analysis and simulation, the designer can create a virtual environment very similar to reality and test the product in many cases of service [Bodi et. al, 2015].

Integrating FEA and QLM together we can create a new Data-cycle process which is very efficient in any quality management system. Figure 3 displays the Data-Cycle which collects data from both real environment and virtual environment.

Using numerical data from simulation and lifecycle data from quality management, the designer has a very clear view about the product and its (reliability, behaviour, maintenance cases, failure modes, crack and deformation), so optimizing the design and apply innovation in next generations-designs will be easier and absolutely cost-time effective. Indeed, this system needs a high level of cooperation between managers and designers to achieve the best results.

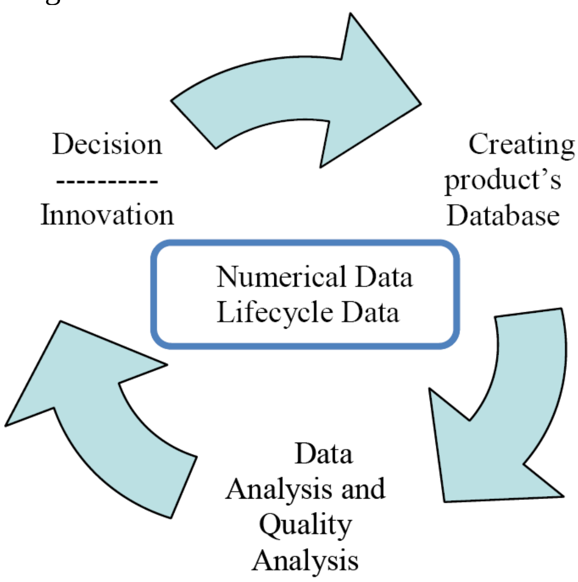

Figure 3: *FEM-QLM Data cycle*

5. Case Study

As a model for the case study, we used a design for turbine-Blade model. The blade is a major important component for gas or steam turbines which makes up the turbine section and extracting energy from the high temperature, high-pressure gas produced by the combustor. The model of the blade completely [Boyce, 2016] effected on turbine efficiency and productivity. Blade design, test and manufacture are accurate and complicated stage because this part will work under structural stresses, thermal stresses and dynamical stresses. The margin of error or failure has to be very small, that's why we used FEA-QLM process to control the blade's design and optimize the model of course based on work conditions and uses [Vaishaly and Ramarao, 2015; Durga and Sai, 2015]. The case is really huge and has many details that are why we take into consideration the parametric design of the blade and structural analysis using FEA. Figure 4 shows blade's geometry and the basic parameters of its design.

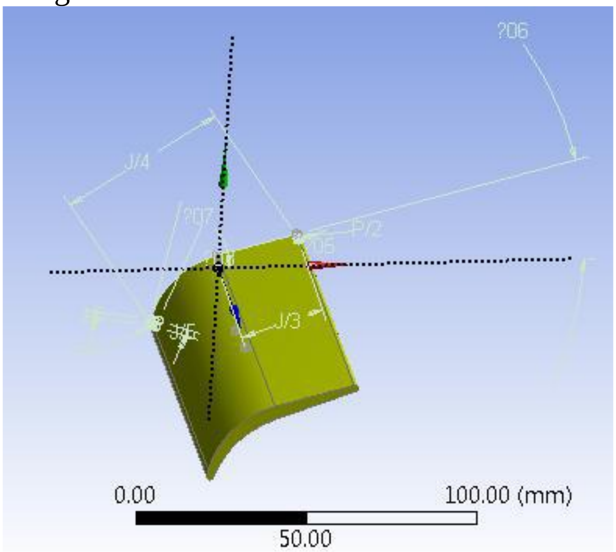

Figure 4: *Blade geometry and design parameters using ANSYS-academic software*

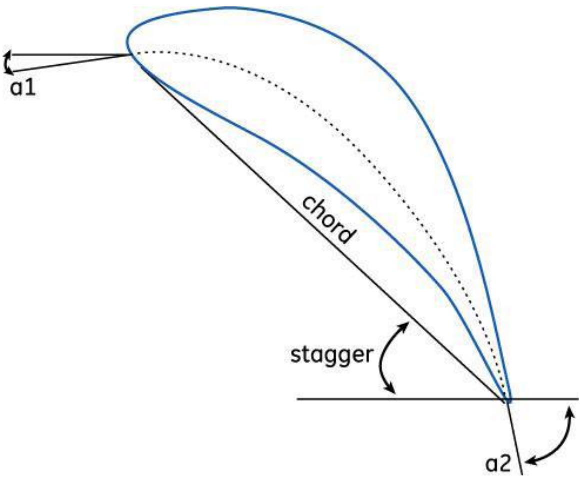

Figure 5: *Design's parameters of turbine's blade*

The model has many design parameters like chord, span length, stagger, head angel (alpha 1, alpha 2...) Figure 5 [Pavuluri and Kumar, 2013].

To apply FEA-QLM system on Blade's model, all mentioned steps above should be followed step by step. Figure 6 shows FEM-QLM integrated system to analyze and improve the design of our Turbine's Blade. Materials and operating conditions have written based on industrial case applied in the factory [Durga and Sai, 2015].

6. Conclusion

At the phase of the product life cycle, it must set the product's requirements to physical shapes and components as a design to build the product. QLM strategy can ensure changes that are incorporated in the improvement next product. Applying the validation of a product using QLM is possible to obtain the highest possible quality accepted on the market. Flexible software as ANSYS allows validating quickly all the transformation in order to optimize the shapes of the parts for the final product. Identifying the impact of these transformations and determining which parameters have a strong influence on product performance can be observed also how will affect the QLM.

In each subsequent design milestones it must identify, evaluate and prepare a contingency plan and assure the risks' management.

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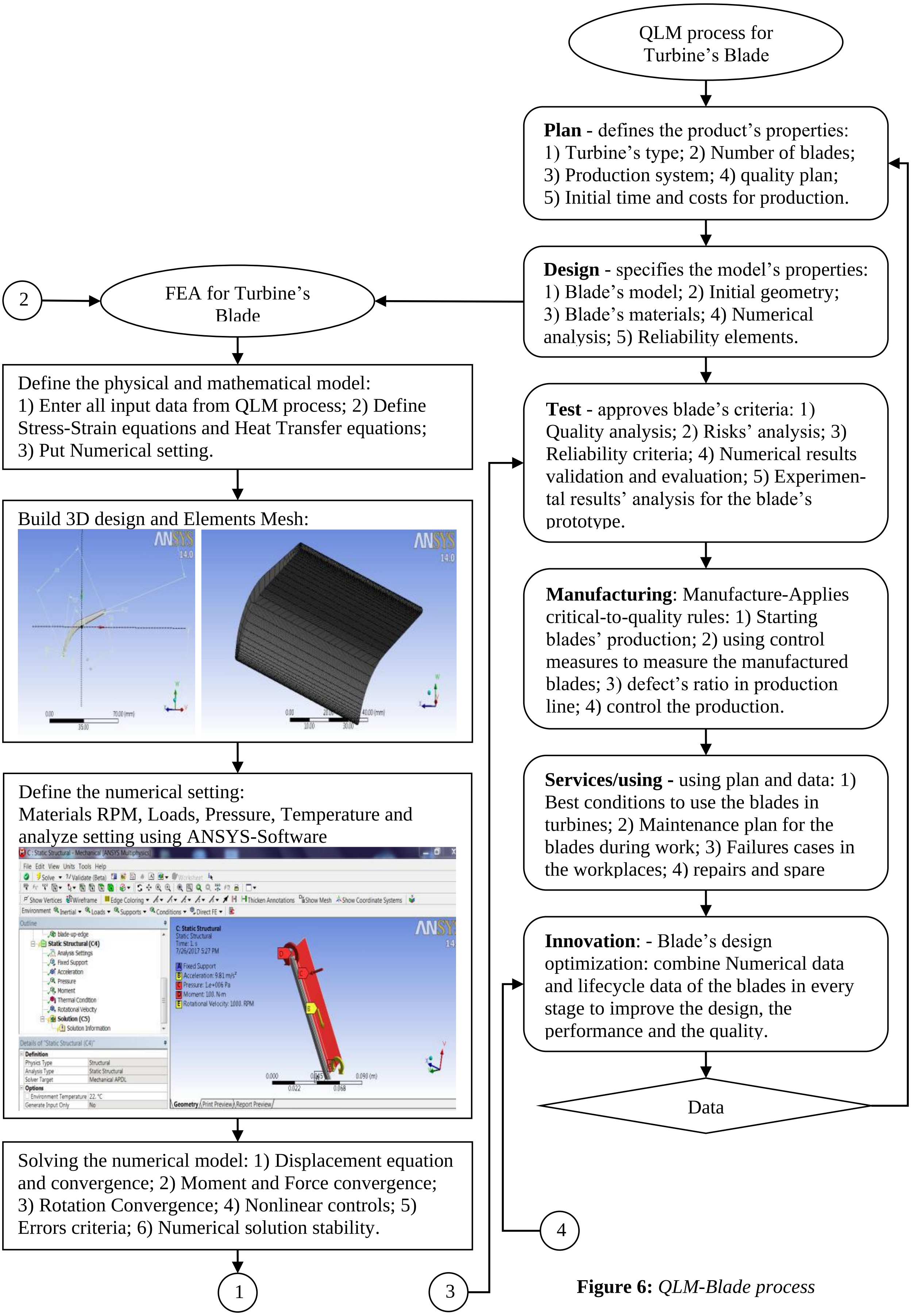

Figure 6: *QLM-Blade process*

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Results evaluation and validation:
1) Estimating stress distribution, strain and deformation, strain energy and failure modes; 2) Test the blade under many cases of loading; 3) Define the critical loads and material strength.

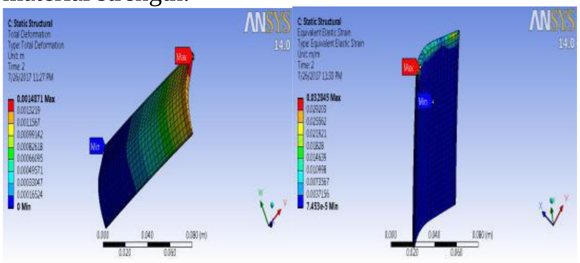


Fig. 8 *Blade deformation and strain distribution*

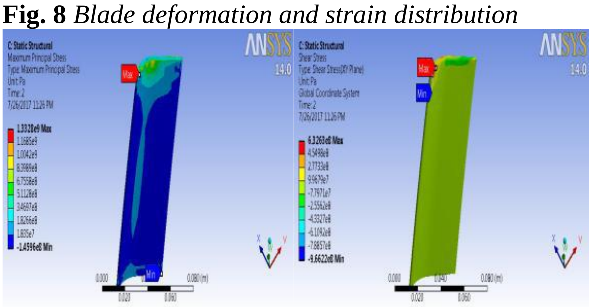
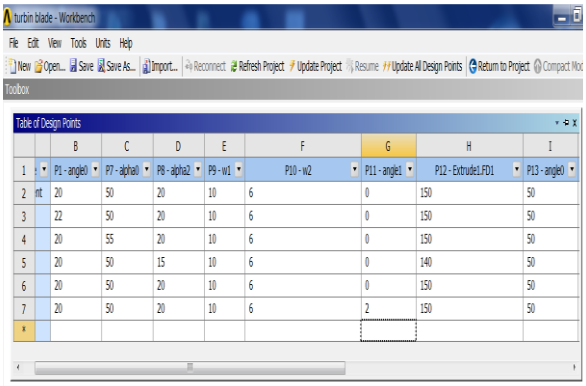


Fig. 9 *Max stress and shear stress distribution on the Blade's model*

Design optimization:
Test different models of the blade and which model is more efficient and effective based on conditions



		B	C	D	E	F	G	H	I
1		P1 - angle0	P7 - alpha0	P8 - alpha2	P9 - w1	P10 - w2	P11 - angle1	P12 - Extrude1.FD1	P13 - angle0
2	nt	20	50	20	10	6	0	150	50
3		22	50	20	10	6	0	150	50
4		20	55	20	10	6	0	150	50
5		20	50	15	10	6	0	140	50
6		20	50	20	10	6	0	150	50
7		20	50	20	10	6	2	150	50
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Fig. 10 *Creating design point for Blade's model and doing the parametric study using ANSYS-Workbench*

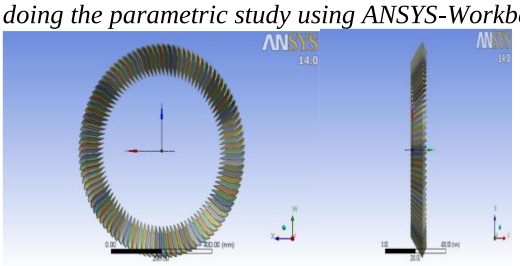

Fig. 11 *Blade assembly model in the turbine, for future research*

2 Data 4 3

Figure 6: *QLM-Blade*

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